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Influence of the Nature of Metals and Modifying Additives on Changes in the Structure of Heavy Oil in a Catalytic Aquathermolysis System

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Abstract—The direction of catalytic aquathermolysis processes involving high-molecular-weight components of heavy oil has been revealed in model experiments, depending on the metal nature and the conditions of the experiments carried out at 300°C in neutral and carbon dioxide media, using oil-soluble carboxylates of the transition metals nickel, iron, cobalt, and copper as a catalyst. The yield and quality of the products formed in the presence of individual metals and their compositions have been determined. Propanol and tetralin have been studied as modifying additives. The viscosity of heavy oil in a carbon dioxide medium has been significantly reduced by using an iron-, cobalt-, and copper-containing catalyst composition together with the propanol additive, as a result of an increase in the amount of saturated and aromatic hydrocarbons and a decrease in the resin content in its composition. An increase in the value of the C_{13}–C_{17}/C_{18}–C_{22} index can serve as a parameter for monitoring the progress of catalytic aquathermolysis processes.

Keywords: high-viscosity heavy oil, composition, properties, aquathermolysis and catalytic aquathermolysis processes

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Recent years have seen extensive, worldwide research on the creation of new highly efficient technologies for extraction and processing of heavy petroleum feedstock, the main types of which are high-viscosity heavy oils and natural bitumens that are in abundance in Permian deposits of the Republic of Tatarstan [1–8]. The recovery of raw material of this kind is fraught with a wealth of problems, which are due to a high concentration of high-molecular-weight hydrocarbons and hetero compounds in it and to the absence of light fractions and are responsible for its low mobility in reservoir conditions, as well as in the transportation and refining processes [8]. The characteristic properties of heavy oils and natural bitumens call for developing new technologies for their upgrading in reservoir conditions, the main purpose of which is the conversion of high-molecular-weight components into low-boiling hydrocarbons. This goal can be achieved using in situ hydrovisbreaking [9, 10] or on-site deep oil processing [8] in the presence of different conversion catalysts [11–19]. There have been studies on the use of water- and oil-soluble compounds of transition metals [11–16] for these purposes, as well as heterogeneous catalysts similar to the conventional catalytic systems for oil refining [15–20]. Research is also underway to intensify these processes by introducing hydrogen donors [11, 13, 14] into the reaction systems and to develop technologies for the introduction of catalysts directly into the reservoir [15]. Much attention in recent years in the extraction of heavy oil has been paid to carbon dioxide [21]. It was shown [22] that when injecting steam and a hydrocarbon solvent into the formation, the interfacial tension at the "heavy oil/water" boundary decreases, which increases the oil recovery. Impacting on heavy oil, technogenic factors lead to a change in its dispersed structure, which can have both positive and negative effect on its technologically important properties [23]. Therefore, the development of technology requires a deep knowledge of the chemical nature of the raw material and the transformation of its composition in both natural and man-made processes.

The purpose of this work was to select the most effective catalyst and the conditions for the reaction medium to intensify the processes of in situ conversion of high-molecular-weight components of heavy oil produced by steam injection drive.